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Black-holes-hedgehogs in the false vacuum and a new physics beyond the Standard Model

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Abstract.   In the present talk, we consider the existence of the two degenerate universal vacua: a) the first Electroweak vacuum at $v = 246$ GeV - "true vacuum", and b) the second Planck scale "false vacuum" at $v_2 \sim 10^{18}$ GeV. In these vacua, we investigated the different topological defects. The main aim of this paper is an investigation of the hedgehog's configurations as defects of the false vacuum. In the framework of the $f(R)$ gravity, suggested by authors in their Gravi-Weak Unification model, we obtained a black hole solution, which corresponds to a "hedgehog" - global monopole, "swallowed" by a black-hole with mass $\sim 10^{19}$ GeV. These black-holes form a lattice-like structure of the vacuum at the Planck scale. Considering the results of the hedgehog lattice theory in the framework of the $SU(2)$ Yang-Mills gauge-invariant theory with hedgehogs in the Wilson loops, we have used the critical value of temperature for the hedgehog's confinement phase. This result gave us the possibility to conclude that there exist triplet Higgs fields which can contribute to the SM at the energy scale $\simeq 10^4 \sim 10^5$ GeV. Showing a new physics at the scale 10÷100 TeV, these triplet Higgs particles can provide the stability of the EW-vacuum of the SM.

1. The investigation

The talk is devoted to studying of topological defects of the universal vacua and to existence of two degenerate vacua in our Universe. The main ideas are published in Refs. [1, 2].

During the expansion after the Planck era, the early Universe underwent a series of phase transitions as a result of which there were arisen such vacuum topological defects (widely discussed in literature) as monopoles or hedgehogs (point defects), strings (line defects), bubbles and domain walls (sheet defects). These topological defects appeared due to the breakdown of local or global gauge symmetries.

This work is essentially based on the discovery that a cosmological constant of our Universe is extremely small, almost zero [3, 4, 5]. We considered a Multiple Point Principle (MPP) first suggested by D.L. Bennett and H.B. Nielsen [6], which predicts the existence in Nature of several degenerate vacua with very small energy density (cosmological constants).

The model developed in this article confirms the existence of the two degenerate vacua of the Universe: The first ("true") Electroweak (EW) vacuum with VEV $v_1 \approx 246$ GeV, and the second ("false") Planck scale vacuum with VEV $v_2 \sim 10^{18}$ GeV.

The main idea of this investigation is the hedgehog's configurations [7, 8] as defects of the false vacuum. We have shown that at superhigh (Planck scale) energies the black-holes-hedgehogs are responsible for the creation of the false vacuum of the Universe. In the framework of the $f(R)$ gravity, we have obtained a solution for a global monopole, which is a black-hole-hedgehog at the Planck scale. Here we have used the $f(R)$ gravity predicted by the Gravi-Weak unification model previously developed by authors in papers [9, 10, 11, 12, 13].

Using the results of Refs.[14, 15] obtained for the $SU(2)$ Yang-Mills theory of the gauge-invariant hedgehog-like structures in the Wilson loops, we have considered the lattice theory giving the critical value of temperature for the hedgehogs confinement phase. Considering the hedgehog lattice theory, we have concluded that hedgehogs can exist only at the energy scale $\mu \gtrsim 10^4$ GeV. Triplet Higgs fields Φ^a (with $a = 1, 2, 3$), which are responsible for the formation of hedgehogs, can show a new physics at the scale ~ 10 TeV.

We reviewed the Multiple Point Principle (MPP) suggested by D.L. Bennett and H.B. Nielsen [6]. In the assumption of the existence of the two degenerate vacua (Electroweak vacuum at $v_1 \approx 246$ GeV, and Planck scale one at $v_2 \sim 10^{18}$ GeV), Froggatt and Nielsen [16] obtained the first prediction of the top-quark and Higgs boson masses, which was further improved by several authors in the next approximations. We devoted to the general properties of topological defects of the universal vacua. We considered topological defects in the "false vacuum", which is presented as a spherical bubble spontaneously produced in the de Sitter-like universe. The space-time inside the bubble, which we refer to as a "true vacuum", has the geometry of an open Friedmann-Lemaître-Robertson-Walker (FLRW) universe. The Gravi-Weak unification (GWU) model [9, 10, 11, 12, 13] as an example of the $f(R)$ gravity. We considered the existence of the de Sitter solutions in the Planck phase. In our calculations of parameters of the GWU-model, where we predicted the Planck scale false vacuum VEV equal to $v_2 \approx 6.28 \times 10^{18}$ GeV. We have investigated the hedgehog's configurations as defects of the false vacuum and we obtained a solution for a black-hole in the framework of the $f(R)$ gravity, which corresponds to a global monopole "swallowed" by a black-hole. The metric around of the global monopole was considered. The mass M_{BH}, radius δ and "horizon radius" r_h of the black-hole-hedgehog were estimated. The lattice-like structure of the false vacuum which is described by a non-differentiable space-time: by a foam of black-holes, having lattice-like structure, in which sites are black-holes with "hedgehog" monopoles inside them. This manifold is described by a non-commutative geometry predicted an almost zero cosmological constant. The phase transition from the "false vacuum" to the "true vacuum", where it was shown that the Electroweak spontaneous breakdown of symmetry $SU(2)_L \times U(1)_Y \to U(1)_{el.mag}$ created new topological defects of EW vacuum: the Abrikosov-Nielsen-Olesen closed magnetic vortices ("ANO strings") of the Abelian Higgs model and Sidharth's Compton phase objects. Then the "true vacuum" (EW-vacuum) again presents the non-differentiable manifold with non-commutative geometry, and again has an almost zero cosmological constant. Here we estimated the black-hole-hedgehog's mass and radius: $M_{BH} \approx 3.65 \times 10^{18}$ GeV and $\delta \approx 0.29\lambda_{Pl} \approx 10^{-21}$ GeV^{-1} near the second vacuum v_2. We emphasize that due to the energy conservation law, the vacuum density before the phase transition is equal to the vacuum density after the phase transition, and we have

$$\rho_{vac}(\text{at Planck scale}) = \rho_{vac}(\text{at EW scale}).$$

Therefore, we confirmed the Multiple Point Principle: we have two degenerate vacua v_1 and v_2 with an almost zero vacuum energy (cosmological constants). This means that our EW-vacuum, in which we live, is stable. The Planck scale vacuum cannot be negative:

$V_{eff}(min1) = V_{eff}(min2)$, these potentials are equal exactly. Hedgehogs in Wilson loops of the $SU(2)$ Yang-Mills theory, and phase transitions in this theory were investigated using the results of Refs. [14, 15]. Their lattice results gave the critical value of the temperature for the hedgehog's confinement phase: $\beta_{crit} \approx 2.5$, and this result gives the value of critical temperature $T_c \sim 10^{18}$ GeV. We show that the hedgehog's confinement happens at energy ~ 10 TeV, which is a threshold energy of the production of a pair of the $SU(2)$-triplet Higgs bosons. We reviewed the problem of the vacuum stability in the Standard Model. We show that hedgehogs can contribute at energy scale $\mu > 10^4$ GeV. Therefore, a triplet Higgs field Φ^a provides a new physics at the scale ~ 10 TeV. We predict an exact stability of the EW-vacuum and the accuracy of the MPP.

2. The results

(i) In this investigation, we were based on the discovery that a cosmological constant of our Universe is extremely small, almost zero, and assumed a new law of Nature which was named as a Multiple Point Principle (MPP). The MPP postulates: *There are two vacua in the SM with the same energy density, or cosmological constant, and both cosmological constants are zero, or approximately zero.* We considered the existence of the following two degenerate vacua in the SM: a) the first Electroweak vacuum at $v_1 = 246$ GeV, which is a "true" vacuum, and b) the second "false" vacuum at the Planck scale with VEV $v_2 \sim 10^{18}$ GeV.

(ii) The bubble, which we refer to as "the false vacuum", is a de Sitter space with its constant expansion rate H_F. The initial radius of this bubble is close to the de Sitter horizon, which corresponds to the Universe radius. The space-time inside the bubble, which we refer to as "the true vacuum", has the geometry of an open FLRW universe.

(iii) We investigated the topological structure of the universal vacua. Different phase transitions, which were resulted during the expansion of the early Universe after the Planck era, produced the formation of the various kind of topological defects. The aim of this investigation is the consideration of the hedgehog configurations as defects in the false vacuum. We have obtained a solution for a black-hole in the region which contains a global monopole in the framework of the $f(R)$ gravity, where $f(R)$ is a function of the Ricci scalar R. Here we have used the results of the Gravi-Weak unification (GWU) model. The gravitational field, isovector scalar Φ^a with $a = 1, 2, 3$, produced by a spherically symmetric configuration in the scalar field theory, is pointing radially: Φ^a is parallel to $\hat{r}$ – the unit vector in the radial direction. In this GWU approach, we obtained a "hedgehog" solution (in Alexander Polyakov's terminology). We also showed that this is a black-hole solution, corresponding to a global monopole that has been "swallowed" by a black-hole.

(iv) We estimated all parameters of the Gravi-Weak unification model, which gave the prediction of the Planck scale false vacuum VEV equal to $v = 2\sqrt{2}M_{Pl}^{red} \approx 6.28 \times 10^{18}$ GeV.

(v) We have shown, that the Planck scale Universe vacuum is described by a non-differentiable space-time: by a foam of black-holes, or by lattice-like structure, where sites are black-holes with the "hedgehog" monopoles inside them. This manifold is described by a non-commutative geometry, leading to a tiny value of cosmological constant $\Lambda \approx 0$.

(vi) Taking into account that the phase transition from the "false vacuum" to the "true vacuum" is a consequence of the electroweak spontaneous breakdown of symmetry $SU(2)_L \times U(1)_Y \to U(1)_{el.mag}$, we considered topological defects of EW-vacuum: the Abrikosov-Nielsen-Olesen closed magnetic vortices ("ANO strings") of the Abelian Higgs model and Sidharth's Compton phase objects. We showed that the "true vacuum" (EW-vacuum) again is presented by the non-differentiable manifold with non-commutative geometry leading to an almost zero cosmological constant.

(vii) By solving the gravitational field equations we estimated the black-hole-hedgehog's mass, radius and horizon radius are $M_h \approx 3.65 \times 10^{18}$ GeV, $R_h \sim 10^{-21}$ GeV^{-1} and $r_h \approx 2.29 R_h$ respectively.

(viii) We considered that due to the energy conservation law, the vacuum energy density before the phase transition is equal to the vacuum energy density after the phase transition: ρ_{vac}(at Planck scale) $= \rho_{vac}$(at EW scale). This result confirms the Multiple Point Principle: we have two degenerate vacua v_1 and v_2 with an almost zero vacuum energy density (cosmological constants). By these considerations we confirmed the vacuum stability of the EW-vacuum, in which we live. The Planck scale vacuum cannot be negative because of the exact equality $V_{eff}(min_1) = V_{eff}(min_2)$.

(ix) Hedgehogs in the Wilson loops of the $SU(2)$ Yang-Mills theory, and phase transitions in this theory were investigated revising the results of Refs. [14, 15]. Using their lattice result for the critical value of the temperature of hedgehog's confinement phase: $\beta_{crit} \approx 2.5$, we predicted the production of the $SU(2)$-triplet Higgs bosons at LHC at energy scale $\mu \sim 10$ TeV, providing a new physics in the SM.

(x) We considered an additional confirmation of the vacuum stability and accuracy of the MPP taking into account that hedgehog fields Φ^a produce a new physics at the scale ~ 10 TeV, and calculating at high energies the contribution of the black-hole-hedgehog corrections to the effective Higgs potential. This result essentially depends on the hedgehog field parameters: mass, radius and mixing coupling constant λ_{hH} of the interaction of hedgehogs with the SM doublet Higgs fields H.

(xi) Please see ref. [17] for detail investigation.

Acknowledgments

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